MR-Guided Focused Ultrasound Ablation of the Rat Liver

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Introduction To study the treatment of hepatocellular carcinoma with MR-guided focused ultrasound (MRgFUS), an appropriate animal model must be established. Rodent models are preferred to larger animals because of the cost associated with survival studies, convenience of experimental setup, and available tumor cell lines. Previously, in FUS studies of the rat liver, the liver has been exteriorized to allow access to the tissue [1], circumventing any effect the ribcage may have on the treatment. To be a useful model, the effects of the ribcage on the US path should not be ignored and the procedure performed without exteriorizing the liver. In the following study we investigate sonicating through the ribcage of the rat and creating *in vivo* thermal lesions localized to the liver with no resulting skin burns while monitoring the treatment using MR imaging to calculate thermal dose and lesion size.

Methods All experiments were performed on the InSightec ExAblate 2000 FUS system installed in a 3T scanner. *In vivo* Sprague-Dewey rats (n=17) were anesthetized and placed head first in prone position on the therapy table after removing the hair on their abdomen with a chemical depilatory cream. A 3-inch surface coil was attached under the rat so that the abdomen was suspended through the coil into a water bath used to achieve acoustic coupling between the animal and the transducer (Fig. 1). Sonications were performed at 1.35 MHz and energy levels of 716-797 Joules. Temperature images and thermal dose maps were reconstructed with PRF-thermometry (GRE, TE=6-8 ms, FOV= 14 cm, slice thickness=3 mm, matrix= 128x128, BW= 31.25 kHz). T2 images and T1 contrast-enhanced (CE) images were acquired after the treatment. Necropsy samples were frozen and 1mm slices photographed. The slice with the largest cross-sectional area was determined to be the focal plane and used to measure the lesion area. These were compared to thermal dose areas (>240 min), to non-enhancing regions on CE images showing the non-perfused area, and to the bright ring outlining the lesion in T2 images corresponding to ablated areas.

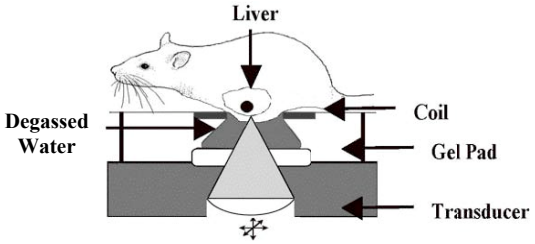

FIGURE 1. Schematic of experimental setup (not to scale)

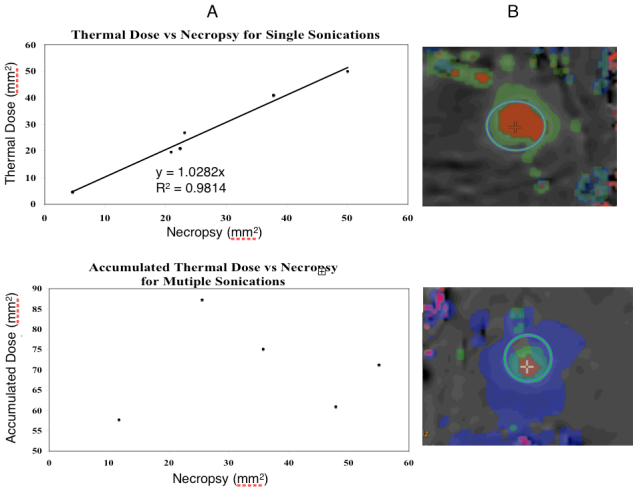

FIGURE 2. A. Area of thermal dose > 240 min created by a single sonication compared to necropsy lesion area. B. Dose map (green contour) of single sonication. Note dose due to noise outside the sonication focus. C. Area of thermal dose of treatments resulting from multiple sonications. D. Accumulated dose from multiple sonications (blue area).

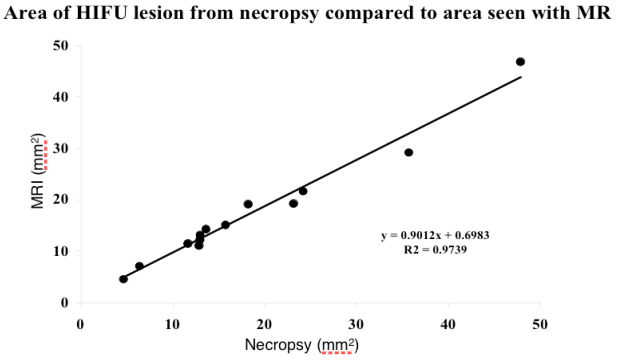

FIGURE 3. Area of HIFU lesion seen with T1 contrast enhanced and T2 imaging compared to actual lesion size measured during necropsy.

Results and Discussion In this *in vivo* study, we found it was possible to create thermal lesions localized to the liver of rats by sonicating directly through the ribcage without thermal burns to the skin. The area of the calculated thermal dose, when compared to the area of the lesion seen during necropsy, corresponded very well for all cases where the lesion was created with a single sonication (Fig. 2 top panel). However, when multiple, overlapping sonications were used to create the ablated area, the accumulated dose overestimated the lesion size considerably (Fig. 2 lower panel). Visual inspection of the individual temperature maps used to calculate thermal dose often showed a single or a small number of temperature maps with noise due to motion or possibly tissue boiling. These caused temperature errors, which led to an overestimation in the resulting dose maps. In the dose maps of the individual sonications it is not obvious that errors are present, so visual inspection or filtering of the acquired temperature maps should be used for more accurate prediction of the necrotic area. Post-ablation CE and T2 imaging closely matched the lesion area measured during necropsy in all cases, as shown in Fig. 3.

Conclusions In this study we have shown that the rat can be a feasible model for MR guided HIFU liver treatments. It is possible to sonicate through the ribs and and predict lesion size from thermal dose images of single sonications. Thermal dose images from multiple sonications overestimate the necrotic area when not processed properly. Post-ablation T2 and CE T1 images correlate well with the ablated area.

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References [1] L. Chen, et al, Ultrasound in Med Biol, 1999; 5; PP 8